THE

AMERICAN NATURALIST.

Vol. xi.—SEPTEMBER, 1877.—No. 9.

REPRODUCTION IN FRESH-WATER ALGÆ.

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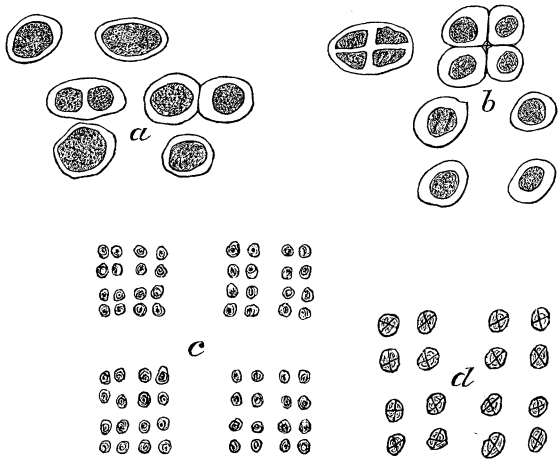
AMONG the higher forms of vegetable life, two distinct methods of reproduction have long been observed, namely, by means of seeds and through some outgrowth from the parent plant. The first method is styled the sexual form, because there is involved in the production of a seed the male element, represented by the pollen grain, and the female part called the embryonal vesicle. In fact, it is the blending of the contents of two separate and distinct cells to form a germ, which under favorable circumstances is capable of producing a plant like the one from which it came. Under the second method fall all those forms of continuing the species other than by means of seeds, which are very common in nature and extensively practiced in the art of horticulture. In essence this is nothing more than multiplication by offshoots or by removal of parts of plants, which when naturally or artificially separated will continue to live and grow.

Let us pass by the interesting and more familiar field of sexual and asexual reproduction among Phænogams, and spend a few moments in looking at these same methods as shown to us by the Algæ of our fresh-water ponds and streams.

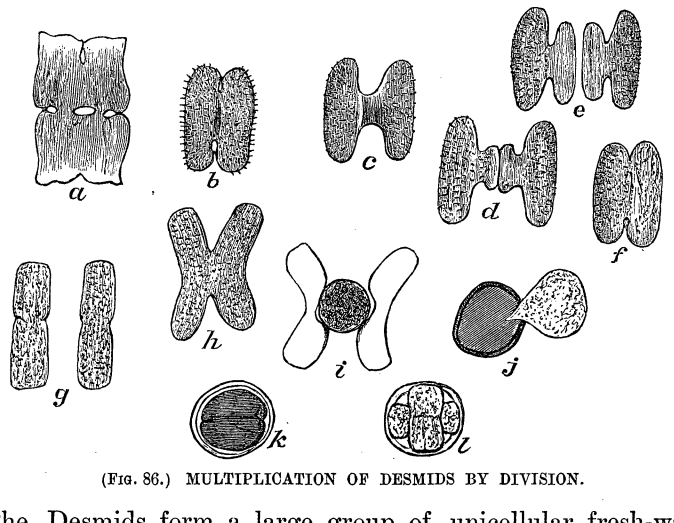
When we have a plant consisting of a single cell, and in the process of time the walls of that cell close in and divide it into two separate and similar cells, each of which soon attains the normal size and divides again in the same manner, we have the clearest illustration of asexual reproduction. The lowest forms of fresh-water Algæ furnish thousands of such examples, where the offshoot and parent plant are not distinguishable because equal in all respects; and in which division of cells results in the multiplication of individuals in the ratio of one to two, as shown in Figure 85, *a*. In other cases the division is not so simple, for, instead of each dividing into two cells, a single unicellular in-

dividual forms four plants, each of which in turn gives rise to four more, so that often, under the microscope, these divisions can be traced through several generations on account of the difference



(FIG. 85.) DIVISION OF CELLS IN ALGÆ.

in size of the individuals and the relations which they bear to each other in space. (Figure 85, *b*, *c*, and *d*.) This simple asexual reproduction is the only method known in these lowest forms of plants.



(FIG. 86.) MULTIPLICATION OF DESMIDS BY DIVISION.

The Desmids form a large group of unicellular fresh-water plants, which have attracted much attention and study owing to the variety and beauty of the forms and markings which they

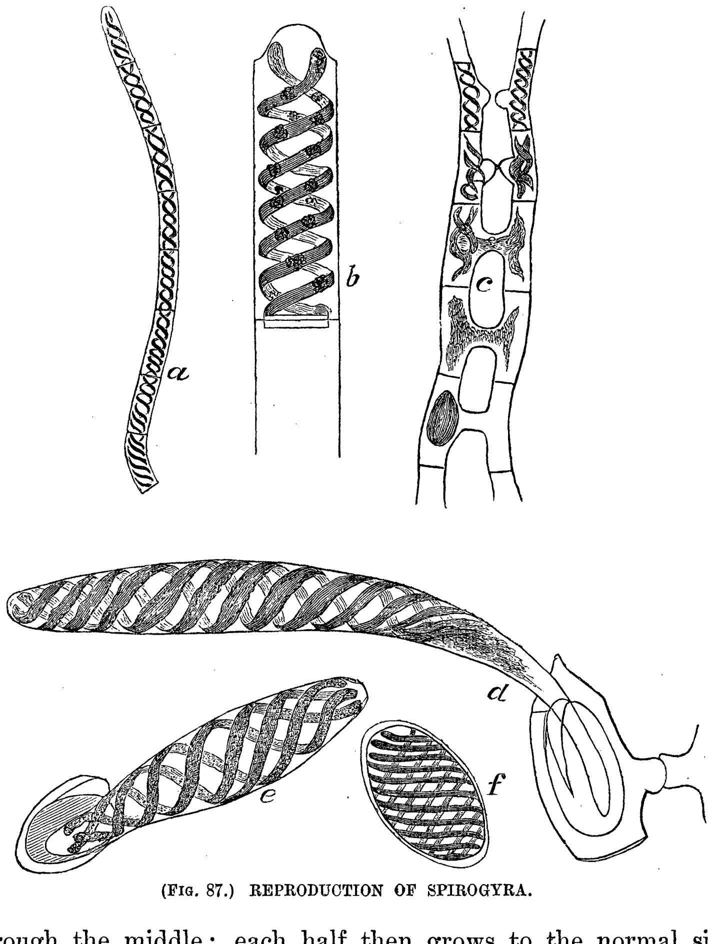
present. The general form of a desmid is usually very symmetrical, it being composed of two parts, of which the one is the exact counterpart of the other. (Figure 86, *a* and *b*.) The asexual form of reproduction is a cell multiplication by division, but differs somewhat from the cases already mentioned. When two desmids are to be made out of one, the first process is the elongation of the neck or part by which the two halves join (*c*). "By this time a new wall has formed inside each half of the isthmus and stretches also across its cavity, forming with its fellow a double partition wall separating the two halves of the old frond. Rapid growth of the newly formed parts now takes place, the central ends become more and more bulging as they enlarge, and in a little time two miniature lobules have shaped themselves at the position of the old isthmus [*d*]. At last, the parts thus formed having assumed the shape and appearance of the original lobules, the two fronds which have been developed out of one separate mostly before the new semicells [*e*] have acquired their full size."[1] This is much the most common form of reproduction, the other being the sexual method, and in one sense a process directly opposite to the one just described, it being the union of two cells to form one. When it is to take place, the outer walls of two desmids lying near each other burst open and the contents of each cell, with its thin inner wall, protrude; these finally blend, and the contents of the two cells flow into one mass (*i*). This new cell thus produced soon takes on a thick outer coat which is frequently ornamented with spines and other markings, and the ultimate result of the whole process is a spore.

In the Desmids the two cells which unite exhibit no sexual differentiation, and botanists have given to all such cases the name of *conjugation* in distinction from *fertilization*, where the male and female organs are apparent. But what becomes of the product of the two conjugated cells? It is a resting spore provided with a thick outer coat, and may sink to the bottom of the pond, where it remains through the winter. When the time for germination arrives its contents divide into a number of masses, each of which becomes a young desmid surrounded by a cell-wall of its own, and is turned out to take care of itself when the wall of the spore is broken away.

Thus far we have looked only at plants which are distinctly unicellular. Now we come to those that are made up of a number of single-celled individuals capable of existing alone, but usually arranged end to end in the form of filaments.

[1] Wood's Fresh-Water Algæ.

The members of the genus Spirogyra are very common in fresh-water ponds, making up much of the filamentous "scum" often seen on the surface. They are easily recognized under the microscope by their green spiral bands of chlorophyll (Figure 87, *a*, and still more enlarged in *b*). New individuals are formed by the simple division of the old cells by means of a partition wall

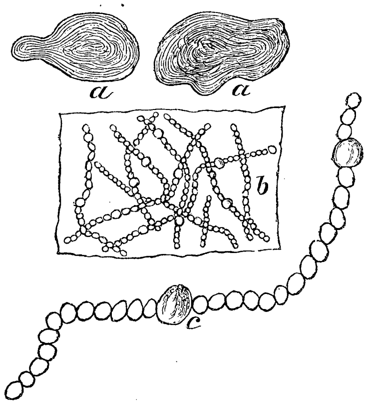


(FIG. 87.) REPRODUCTION OF SPIROGYRA.

through the middle; each half then grows to the normal size and again divides, thus increasing the length of the filament. Conjugation takes place between the cells of adjoining filaments. The first perceptible change is a contraction in the spirally arranged protoplasmic contents into a somewhat compact and irregular mass, followed by a bursting of the cell-wall, out of which a process is pushed, which, meeting with another similar one from

an adjoining cell, blends with it, and the contents of one cell pass over into the other. Two filaments can frequently be found lying nearly parallel, the cells of the one filament conjugating with those of the other throughout the whole length. In conjugation the deep green spiral bands are therefore destroyed, and in their place the dark brown spores are produced; so that in a floating mass of Spirogyra, when this process takes place, the beautiful green is lost and a pale, sickly, dirty material is seen in its stead, appearing as if dead when in reality only preparing itself to live over until another spring. Germination takes place by the contents of the spore pushing out into a filament, as shown in Figure 87, *d*, *e*, and *f*, drawn after a plate by Pringsheim, a noted cryptogamic botanist.

In the genus Zygnema, quite closely related to the Spirogyra, the spores often do not form in either of the cells, but remain in the enlarged centre of the uniting tube, leaving both filaments empty and giving a ladder-like appearance to the whole affair. Again, in other closely related genera, conjugation takes place between the adjoining cells of the same filaments by different methods in different species. In some a small tube is thrown out from each of the two cells, which meet and form a passage for the transfer of the contents of one cell to that of the other.

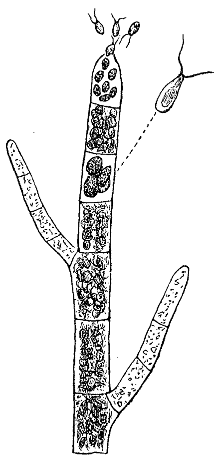


(FIG. 88.) NOSTOC.

The Nostocs grow in water, but are more commonly found on damp ground as gelatinous spherical masses or colonies (Figure 88, *a*, *a*). When a small portion of one of these slippery balls is placed under the microscope it is seen to consist of a multitude of filaments, resembling strings of beads, imbedded in an amorphous jelly (*b*). In these strings there are at irregular distances certain cells, larger than the others, called heterocysts. In speaking of the method of reproduction of these plants we cannot do better than employ the language of Thurets, who has made a thorough study of them. He says: "The jelly of the old colony becomes softened by water, the portions of the threads lying between the heterocysts become detached, separate from the jelly and straighten, while the heterocysts themselves remain in the

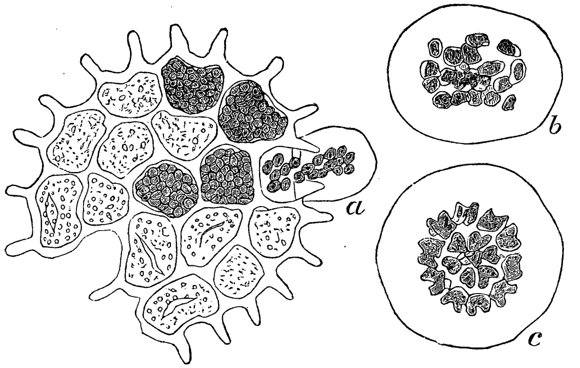
jelly. After they have entered the water the old portions of the thread become endowed with motion, like the oscillatoreæ, and their exit is apparently caused by this movement. The roundish cells of the filaments now grow transversely, that is, vertically, to the axis of the filament, become disk-like, and then divide, the division planes being parallel to the axis of the old filament, which now consists of a series of short threads, the axis of whose growth is vertical to its own. The numerous threads which are thus formed continue to elongate and to increase the number of their cells; they then curve, place their two terminal cells in contact with those of the next row, and thus the whole unite into a single curved Nostoc-filament. Individual cells, apparently without any definite law, become heterocysts. In the mean time the gelatinous envelope of the new filament is developed, and the original microscopic substance attains or even exceeds the size of a walnut by continuous increase of the jelly and division of the cells."

In the Confervæ family reproduction is effected by means of motile asexual bodies called *zoöspores.* The members of the genus Cladophora, a portion of one of which is highly magnified in Figure 89, are quite common, deep green, irregularly branched algæ. When these zoöspores are to form, the protoplasmic contents of certain cells contract into oval masses, each of which upon its escape through the broken cell-wall moves away in the water by means of two vibratile cilia which are attached to one end of the spore. This rotary and progressive motion lasts for some time, after which the body comes to rest, loses its cilia, and, attaching itself to some support, germinates and produces a new Cladophora. There are frequently two distinct sizes of these asexual spores produced in separate cells of the same plant, as seen in the figure; the large ones are called macrozoöspores, and the small ones microzoöspores. It has been stated by Pringsheim that the microzoöspores conjugate, in which case we would have sexual action taking place between asexual spores. It is certainly quite interesting to see these little animal-like bodies moving rapidly around inside the mother cell, as well as darting away upon making their exit. Sometimes two or more



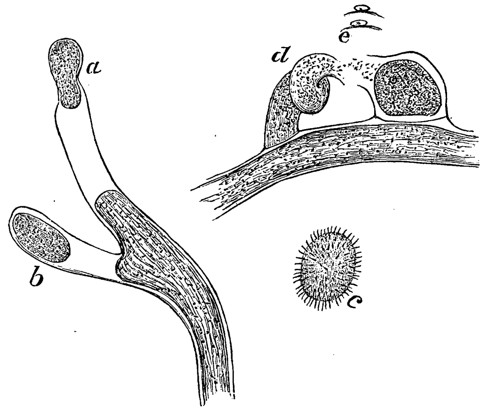
(Fig. 89.) CLADOPHORA.

will reach the opening at the same time when there is room for the passage of only one at a time, and even here among these protoplasmic forms there seems to be an exhibition of selfishness often bordering on wrath.



(Fig. 90.) PEDIASTRUM.

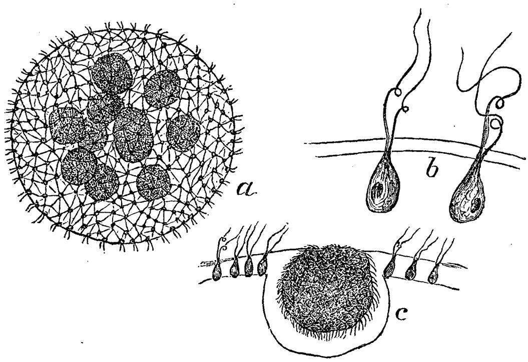
The family to which the Pediastrum belongs is distinguished by each cell forming a large number of motile spores, which remain together as they escape, and grow into a new disk-shaped cluster. In Figure 90 (which is a copy from A. Braun) is shown an old community where many of the cells have discharged their contents in a manner seen at *a*. Soon after the escape of a cell's contents a form as shown at *b* is assumed, the cluster being surmounted by a mass of jelly. A more advanced state of development is given at *c*, where the form of the mature community is discerned.



(Fig. 91.) VAUCHERIA.

The genus Vaucheria is a large one, and is made up of species of green, single-celled, often branching algæ, which grow most frequently on the moist borders of fresh-water streams. These plants are pleasant ones to study, and exhibit very well both sexual and asexual methods of reproduction. At *a* in Figure 91 is an enlarged portion of a filament, from the tip of one branch of

which a part of the contents is escaping, while in the other branch an oval body is seen. These represent the asexual spores, a more enlarged example of which is seen at *c*, and are nothing more than portions of the green protoplasmic contents of the filaments which contract and escape through the rupture at the tip. These spores are covered with a number of cilia, by the movement of which they are able to move about quite rapidly for a short time; then, coming to rest, they germinate, and produce a new Vaucheria. When a sexual spore is produced the process is somewhat different. At certain points on the filament, not far distant from each other, two projections arise: the one grows more slender than the other (*d*) and becomes much twisted upon itself. This is the male organ, called *antheridium*, and in it are produced the *antherozoids*, small bodies (*e*) provided with two cilia for movement; they resemble the zoöspores of the Cladophora, though having a quite different office to perform. The other projection is the



(Fig. 92.) VOLVOX.

female organ, *oögonium*, and is usually of an ovoid shape and filled with granular matter. When the time for fertilization comes, the wall of this organ is ruptured at the end nearest the antheridium, from which there passes out at the same time a mass of antherozoids, some of which find their way to the contents of the oögonium and fertilize it. Soon a new growth takes place in this newly fertilized body, and a double cell-wall is formed over it, the whole becoming a well-protected, resting spore; it is provided with no cilia and therefore has no movement of its own.

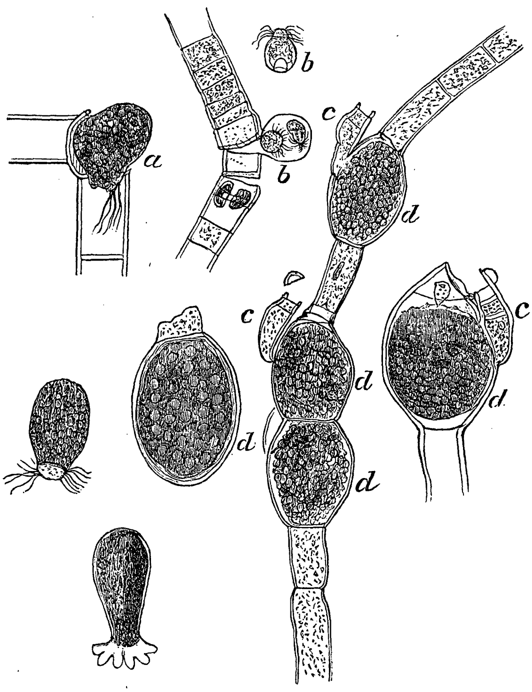
Is it not easy to trace the similarity between the sexual reproduction of Vaucheria and that of flowering plants?

The Volvocineæ comprise a peculiar group of plants, the mem-

bers of which are always in motion, and for this reason have often been classed in the animal kingdom. Figure 92, *a*, gives an enlarged view of a Volvox, which has the general appearance of a sphere studded over with a multitude of bodies arranged at quite regular distances and provided with two cilia. An enlarged view of a section of the outside of one of these spheres, with two of these ciliated bodies, is shown at *b*. Each of these bodies is considered an individual, and therefore the whole sphere is, like an oak-tree or grape-vine, a community of individuals. Asexual reproduction takes place by one or more of these individuals increasing rapidly in size and their contents dividing up into what are to develop into new individuals, forming thus a number of young communities within the old one, several of which are shown as dark, round bodies in *a*. When these young spheres have attained considerable size (*c*) they escape and become free and independent colonies. "The succession of generations of motile families is brought to an end by the formation of resting spores. The separate primordial cells of the last motile family lose their cilia, and surround themselves with a firm, closely adherent cell-wall. They accumulate at the bottom of the water, and there grow into large green balls, the color of which passes over when mature into red. Only when these resting cells have remained dry for a long time are they in a condition when again moistened to develop gradually generations endowed with motion. The sexual reproduction is brought about in this family by the gelatinous envelopes of the young families softening and setting free the separate cells, which move around by means of their cilia. When two of these cells meet they coalesce into a single body, the spore, which germinates and produces a new community after a period of rest."

Members of the genus Œdogonium grow frequently in stagnant pools and are not very attractive to the naked eye, though when viewed through the microscope they become objects of interest to many. Their somewhat complicated methods of reproduction are given so clearly by J. Sachs, in his Text-Book of Botany, that we cannot refrain from using his language in describing them, as well as copying the plate which he uses from Pringsheim. "The reproduction of the Œdogonieæ takes place by asexual swarm-spores and by oöspores produced sexually. An alternation of generations takes place in the following manner: From the oöspores which have remained at rest for a considerable period, several (usually four) swarm-spores are immediately formed,

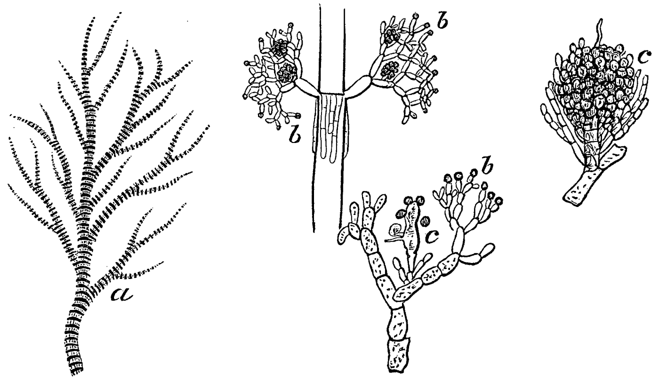
which produce asexual, that is, swarm-spore-forming plants, from which similar ones proceed, until the series of them is closed by a sexual generation (with formation of oöspores); but the sexual plants produce swarm-spores as well. The sexual plants are either monœcious or diœcious: in many species the female plant produces peculiar swarm-spores, out of which proceed very small male plants (dwarf males). The swarm-spore is developed in an ordinary cell of the filaments by the contraction of its whole protoplasmic substance (Figure 93, *a*); it becomes free from the



(FIG. 93.) ŒDOGONIUM.

mother-cell, the cell-wall splitting by a transverse slit into two very unequal parts. The swarm-spore is encircled at its hyaline end — the anterior end during swarming — by a crest of numerous cilia. The spermatozoids are very similar in form to the swarm-spores, but much smaller (*b*, *b*); their motion, due to a crest of cilia, is also less. The androspores, from which the dwarf male plants arise, are produced from mother-cells similar to those which give birth to the spermatozoids. After swarming they fix themselves to a definite part of the female plant, on or near the oögonium, and after germination produce at once the antheridium-

cells, and in them the spermatozoids (*c*, *c*, *c*). The oögonium becomes at first more completely filled with contents than the remaining cells; immediately before fertilization the protoplasm contracts and forms, as in Vaucheria, the oöspore, in the interior of which the grains of chlorophyll are densely crowded. Immediately after fertilization the oöspore surrounds itself with a membrane which afterwards, like its contents, assumes a brown color. The oöspore remains inclosed in the membrane of the oögonium, which separates from the neighboring cells of the filament and falls to the ground, where the oöspore passes its period of rest. When it awakes to new activity the oöspore does not itself grow into a new plant, but its contents divide into four swarmspores, which escape together with the inner skin of the oöspore, and, after this latter is dissolved, swim away. After becoming stationary each grows into a new plant."



(Fig. 94.) BATRACHOSPERMUM.

The last example, under this head, which space will admit of giving is one of a very few members of the family of red seaweeds, which condescends to live in fresh water, namely, Batrachospermum, or, as it is commonly called, frog-spittle. It grows in tufts upon the rocks and pebbles in the bottom of running streams, a small portion of which is shown in Figure 94, *a*, as it appears to the naked eye. The plant is made up of a central axis with a large number of branches radiating from it at quite regular intervals, giving a necklace-like appearance to the filaments. The male element is in the shape of small cells borne singly on the tips of the branches (*b*, *b*). The female part is a large, peculiar-shaped cell situated on a main branch down near the central cylinder (*c*). The antherozoids have no cilia, and fall from their attachments and are carried about by the water. When

one or more of them come in contact with the upper portion of the female cell they blend with it and their contents are absorbed and fertilization is effected. Soon a rapid growth of filaments and cells takes place at the base of the female organ as a result of this fertilization. In fact there is formed a naked cluster of spores (*c*) from these filaments, all fertilized by the single sexual act upon the central female cell.

In these few pages the endeavor has only been to point out a few of the leading methods of asexual and sexual reproduction among fresh-water algæ, and we feel in closing that the vast subject has been but here and there touched upon. But enough has been said to show that even in these lowly forms the *too often supposed* sameness of reproduction loses itself in variety of methods and multiplicity of changes.

SURFACE GEOLOGY OF THE MERRIMACK VALLEY.[1]

BY WARREN UPHAM.

THE highest fountains of Merrimack River are Eagle Lakes, on Mt. Lafayette, 1090 feet below its summit and 4170 above the sea. The source of the straight river is a lake which lies in the deep Franconia Notch, beneath the jutting rocks of the Profile. This stream is at first inclosed by high mountain ranges, and descends more than 1200 feet in its first nine miles. Distances and heights along this river are as follows : Profile Lake, about 1950 feet above the sea ; mouth of East Branch, 9 miles, 710 ; at Plymouth, 28 miles, 468 ; at New Hampton, 39 miles, 438 ; mouth of Smith's River, two miles below Bristol, 45 miles, 320 ; mouth of Winnipiseogee River at Franklin, 55 miles, 269 ; mouth of Contoocook River at Fisherville, 66 miles, 249 ; mouth of Soucook River, 76 miles, 199 ; Amoskeag Falls at Manchester, 89 miles, 179 to 123 ; at line between New Hampshire and Massachusetts, 108 miles, 90 ; Pawtucket Falls dam, Lowell, 117 miles, 87 ; Essex Company's dam, Lawrence, 128 miles, 39. The entire length of this river is about 155 miles, and its last twenty miles are affected by the tide.

The Merrimack Valley in New Hampshire is comparatively straight, and forms a continuous line of depression which is a principal feature in the topography of the State. Its course is

[1] This essay is principally based upon explorations made for the Geological Survey of New Hampshire, and will be more fully presented in vol. iii. of the report on that survey.